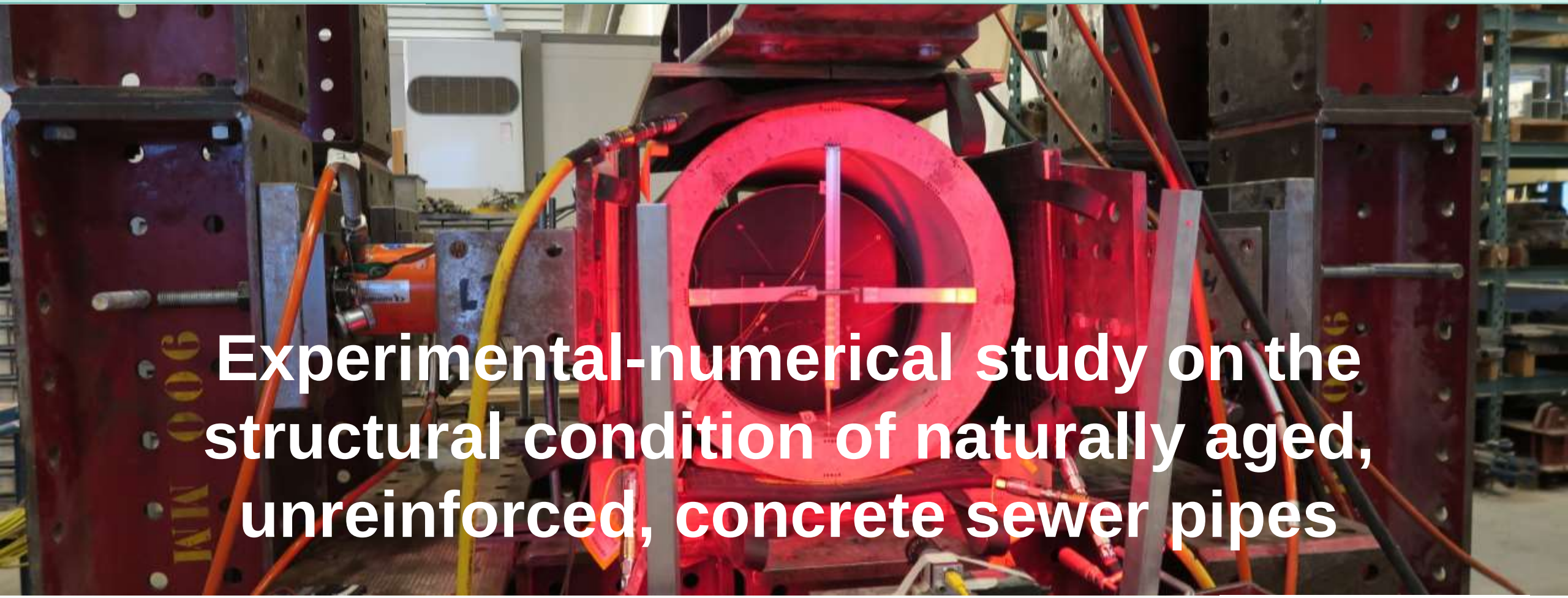

# Experimental-numerical study on the structural condition of naturally aged, unreinforced, concrete sewer pipes

PhD-project

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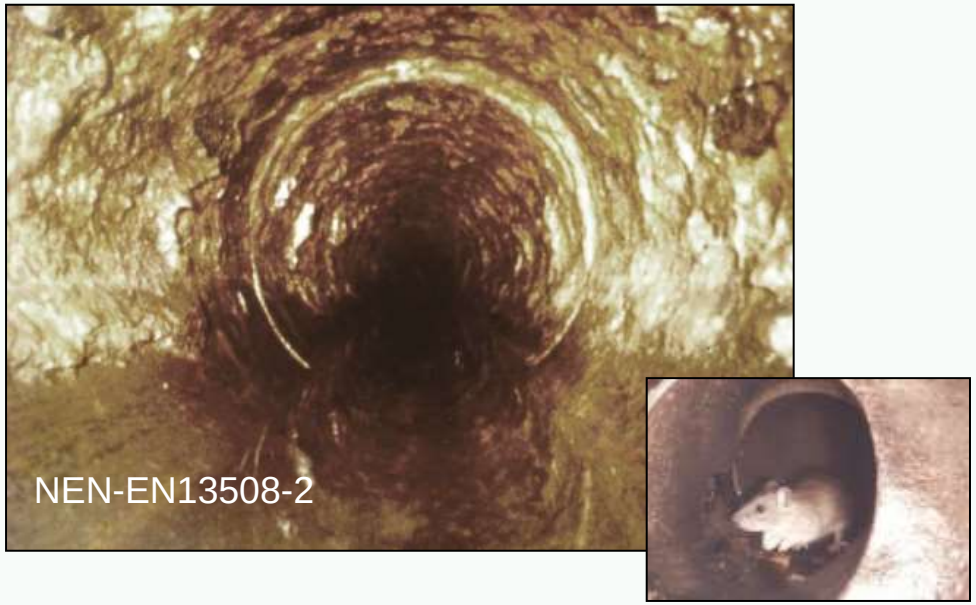
## Goal of the project:

*Provide a scientific basis and practical recommendations for the condition assessment of concrete sewer pipe systems to help municipalities improve the decision-making process on the maintenance and replacement of these systems*




# Overview of the experimental-numerical study



**Large group of 18 new and 35 naturally aged unreinforced concrete sewer pipes**

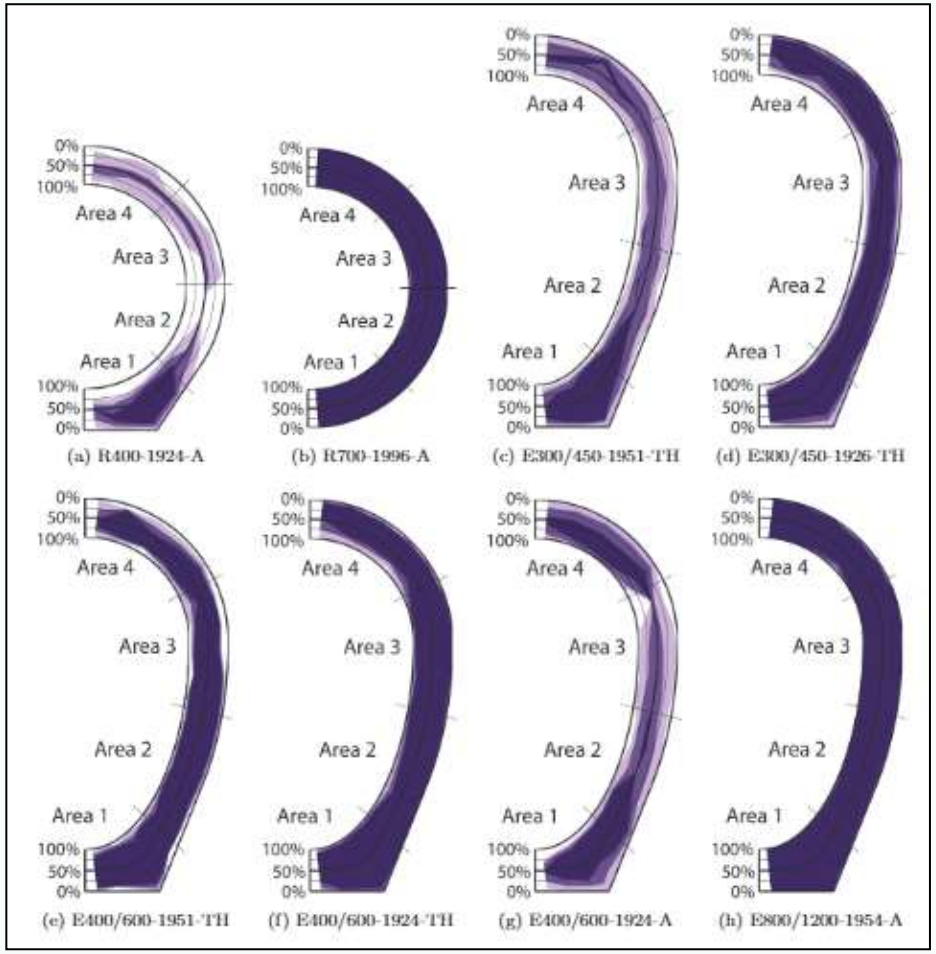
| **Type and degree of deterioration** | **Material properties** | **Full-scale experiments** | **Numerical analyses** |
|---|---|---|---|
| Surface condition qualification<br>Residual alkalinity<br>XRD-analyses | Compressive strength<br>Young's modulus<br>Tensile strength<br>Mode I toughness | Load-bearing capacity<br>Failure behaviour | Parameter variation study<br>Determining factors for structural capacity |

**Conclusions and practical recommendations**

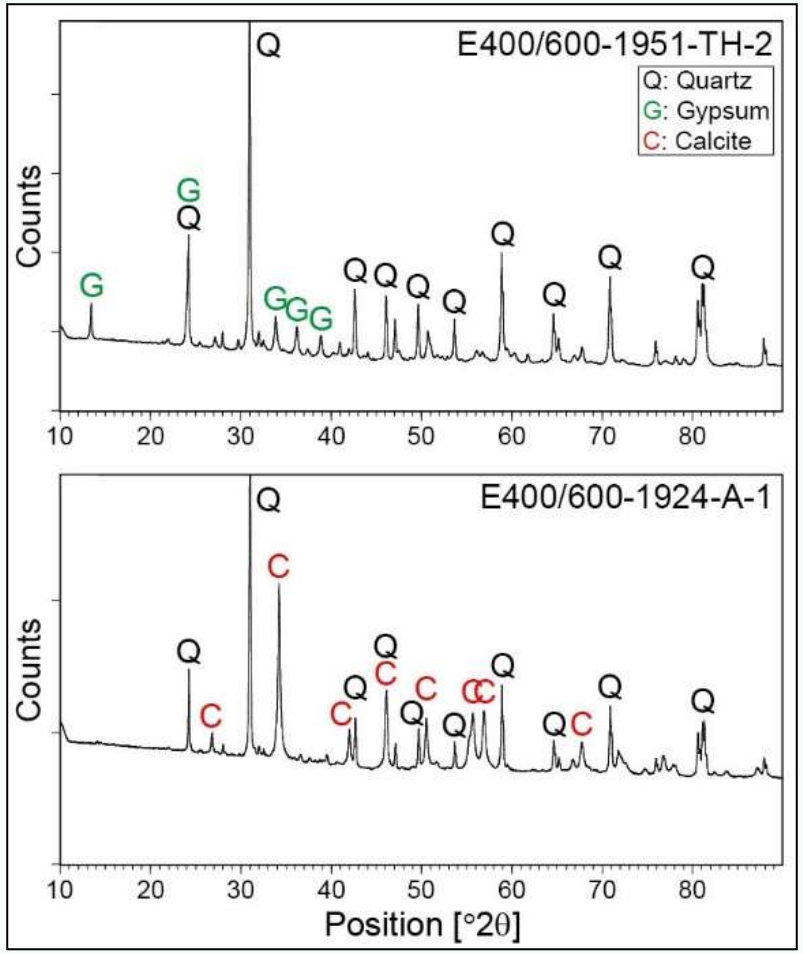
# Type and degree of deterioration

## Surface condition qualification


## Residual alkalinity tests



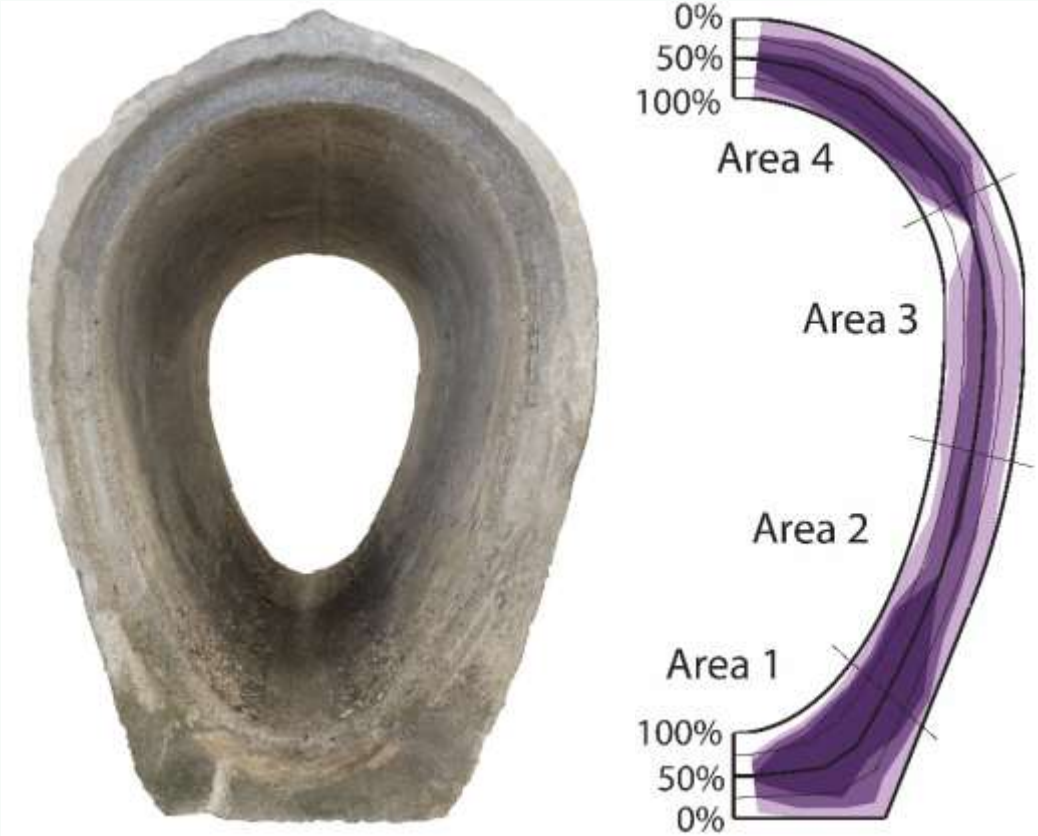

## XRD-analyses



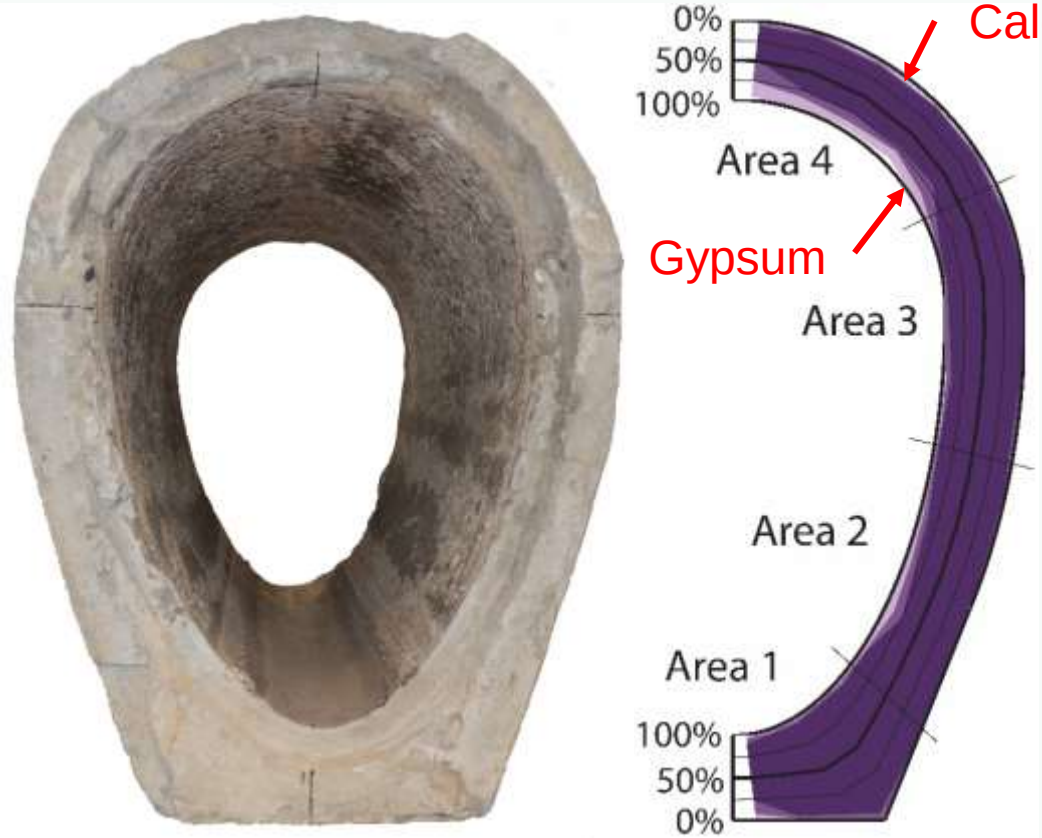
# Type and degree of deterioration



E400/600-1924-A




E400/600-1924-TH




Alkaline, healthy concrete

Non-alkaline, deteriorated concrete

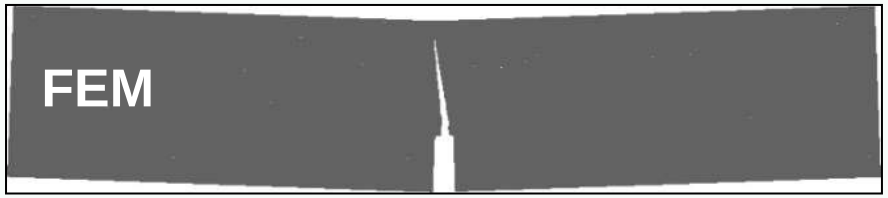
# Material properties

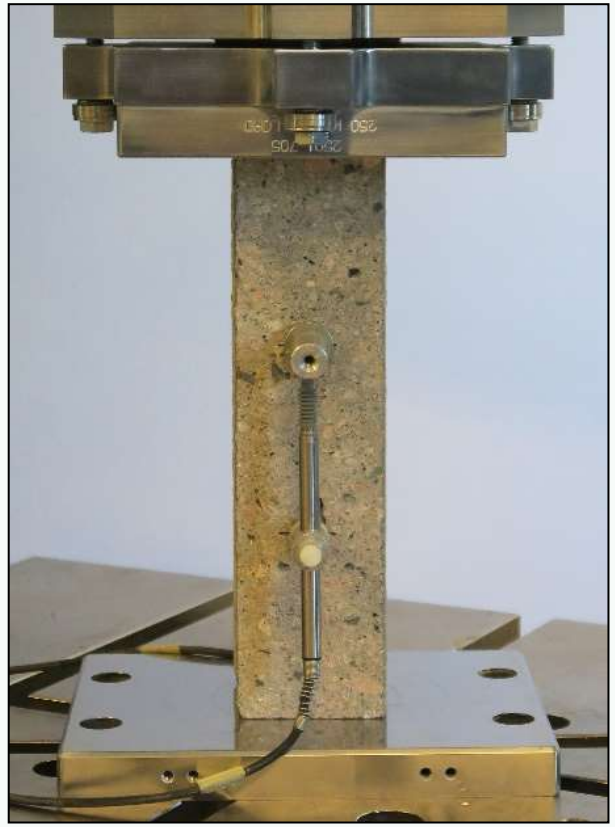
**Uniaxial compression tests**

- Compressive strength
- Young's modulus

**Three-point bending tests**

- Tensile strength
- Mode I fracture toughness



# Material properties



| | Sewer pipe | Compressive strength [N/mm²] | Young's modulus [N/mm²] | Tensile strength [N/mm²] | Mode I fracture toughness [N/mm] |
|---|---|---|---|---|---|
| new | R400 | 85.1 | 48697 | 4.6 | 0.080 |
| | R500 | 80.0 | 44413 | 3.9 | 0.080 |
| | E400/600 | 85.5 | 47067 | 4.1 | 0.105 |
| | **All sewer pipes** | **83.5 (8.5)** | **46726 (2327)** | **4.2** | **0.088** |
| Naturally aged | R400-1924-A | 44.6 | 31338 | 2.9 | 0.090 |
| | R500-1997-A | 67.7 | 52193 | 5.0 | 0.115 |
| | R700-1996-A | 64.5 | 46412 | 3.2 | 0.125 |
| | E300/450-1951-TH | 46.7 | 41916 | 2.1 | 0.115 |
| | E300/450-1926-TH | 45.1 | 43911 | 2.8 | 0.150 |
| | E400/600-1951-TH | 49.8 | 37910 | 2.2 | 0.100 |
| | E400/600-1924-TH | 61.1 | 39293 | 3.1 | 0.120 |
| | E400/600-1924-A | 50.8 | 42478 | 2.8 | 0.090 |
| | E800/1200-1924-A | 83.1 | 45746 | 3.0 | 0.150 |
| | **All sewer pipes** | **57.0 (10.9)** | **42355 (4577)** | **3.0 [1.4/5.6]** | **0.117 [0.070/0.200]** |

**32% lower**

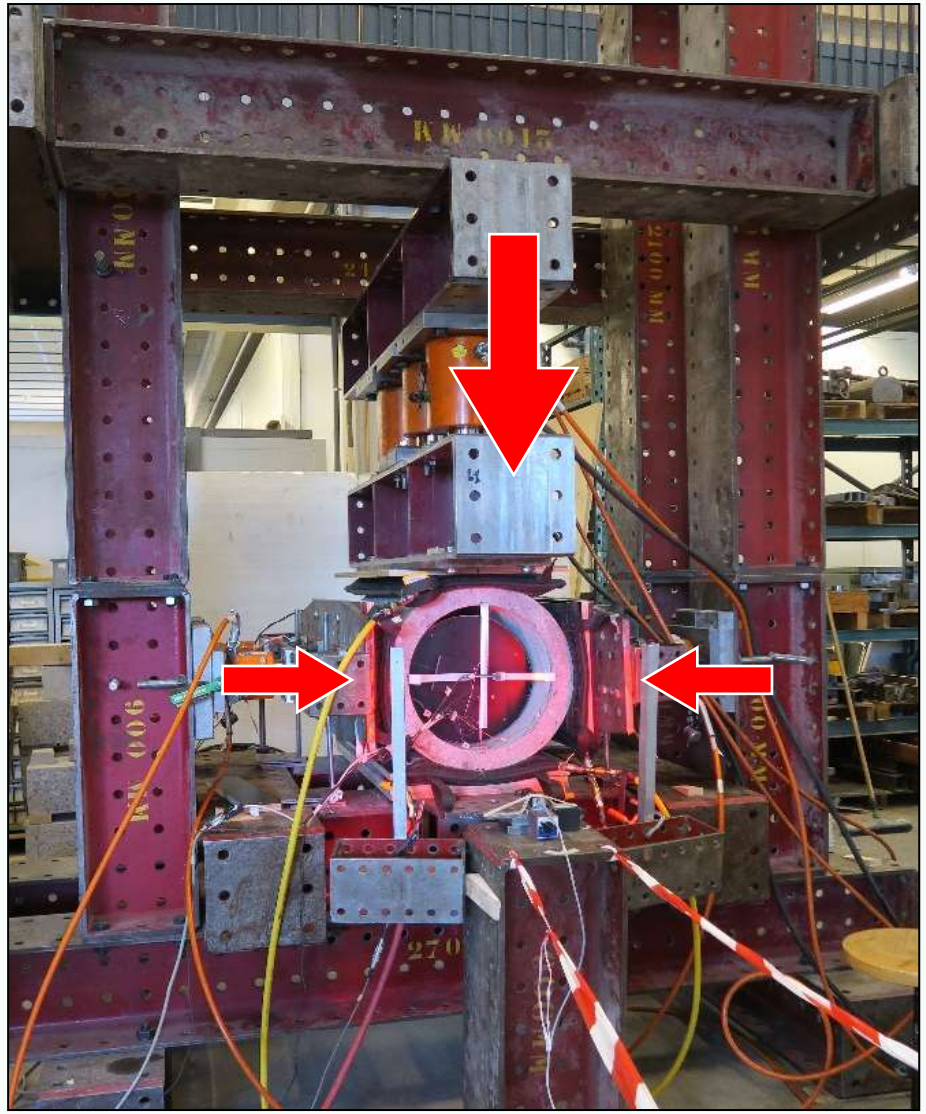
**9% lower**

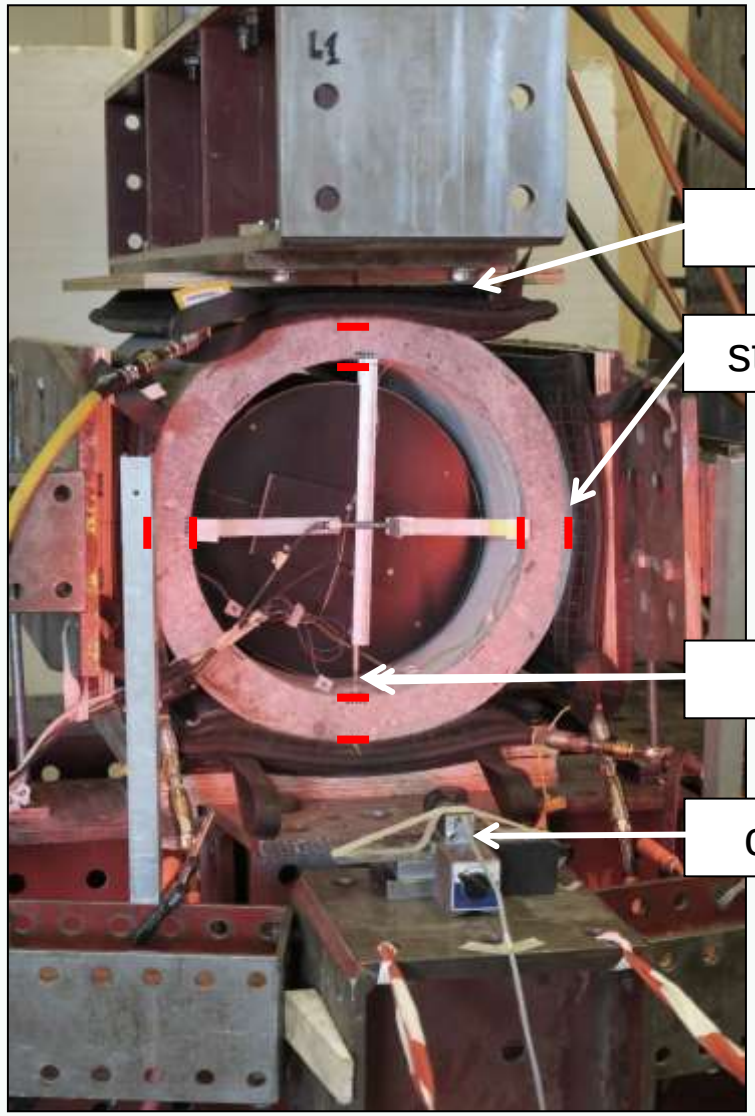
**29% lower**

**25% higher**

# Full-scale experiments



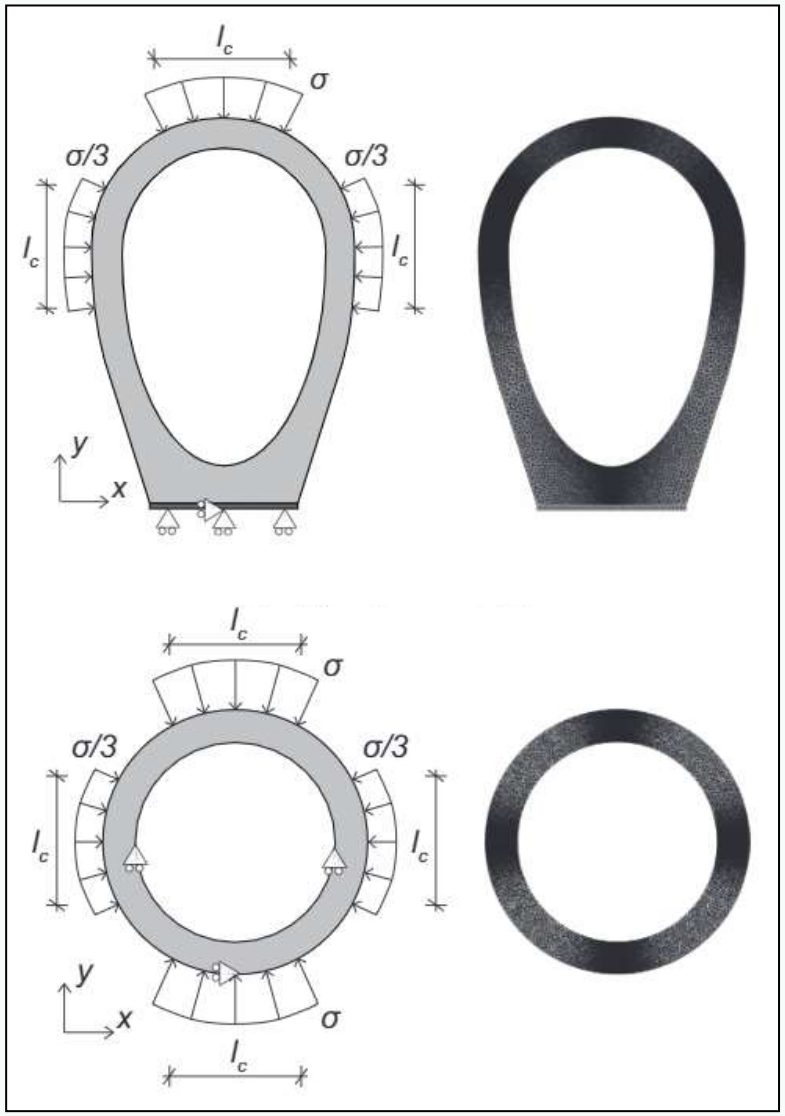




# Full-scale experiments



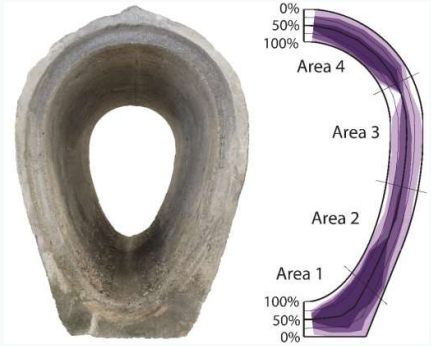
# Numerical analysis



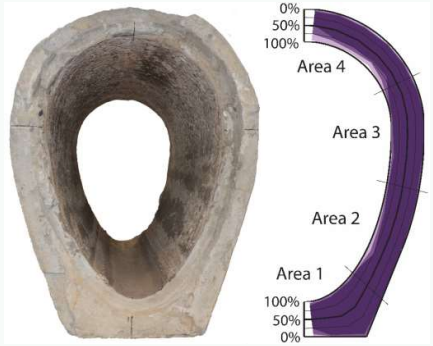

**Effects on structural failure of:**

- Spread in material properties
- Reduced wall thickness (inside)

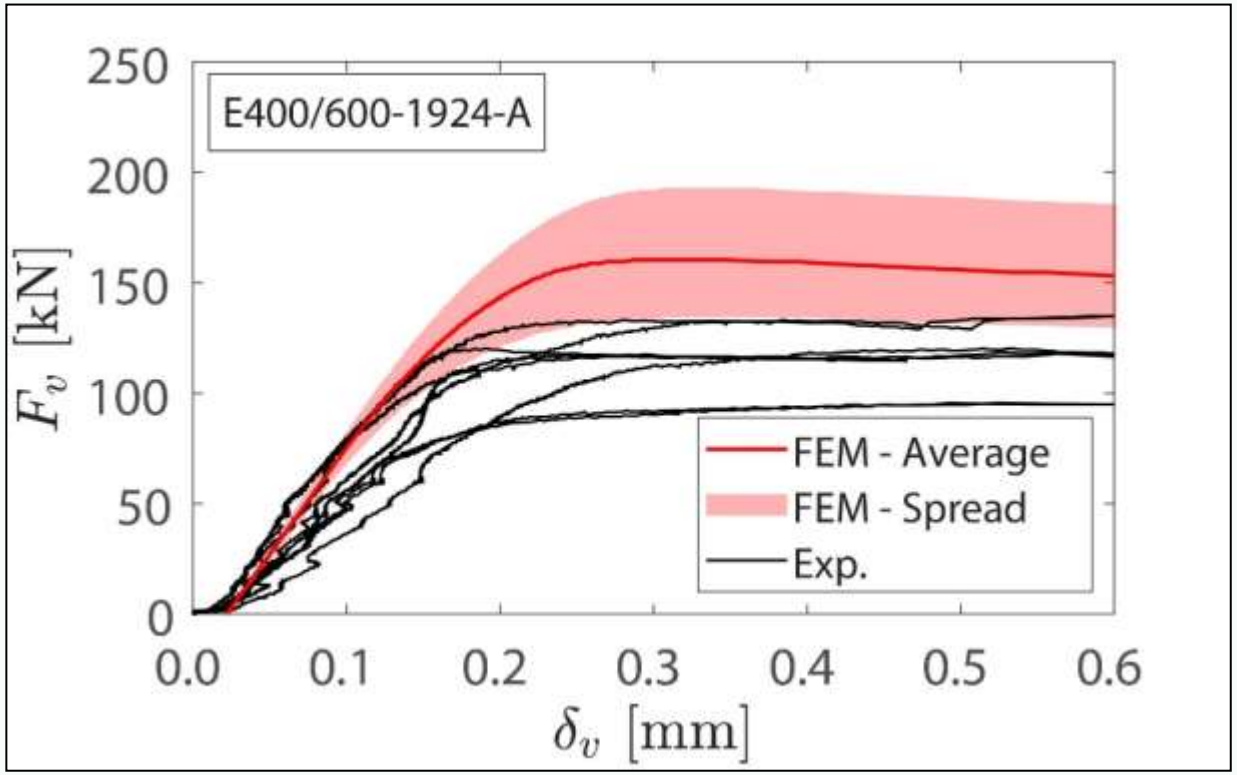
## Spread in material properties

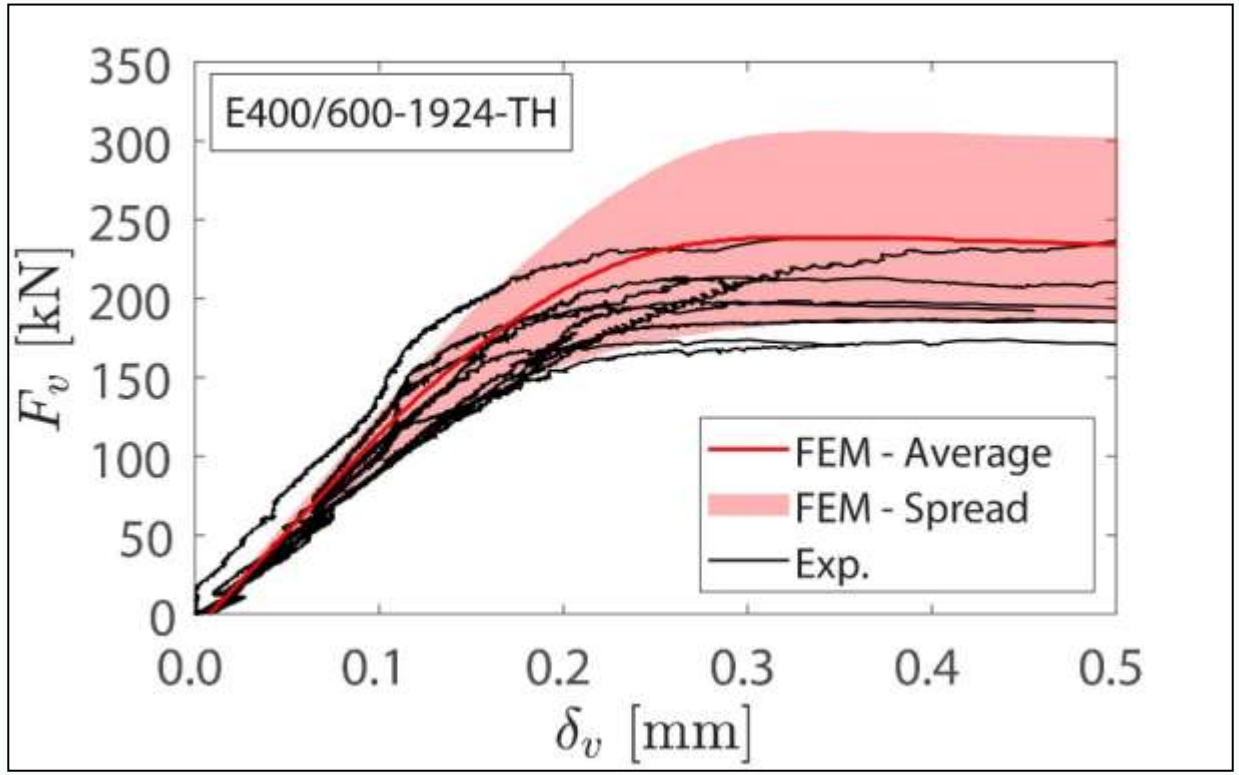



$F_{max;Exp.}$=117kN
$F_{max;FEM}$=160kN (+37%)

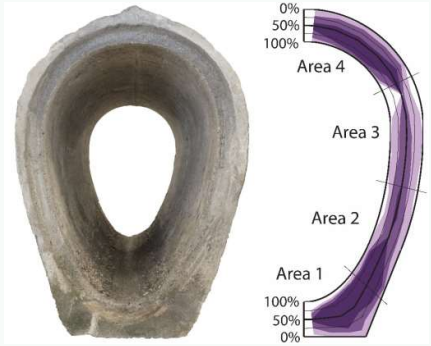



$F_{max;Exp.}$=207kN
$F_{max;FEM}$=239kN (+15%)

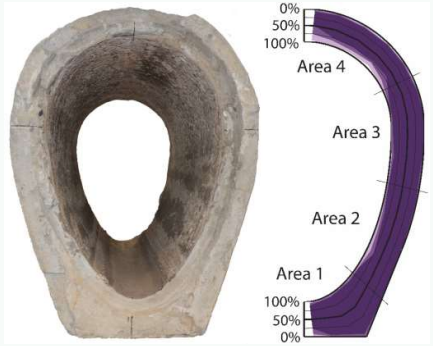


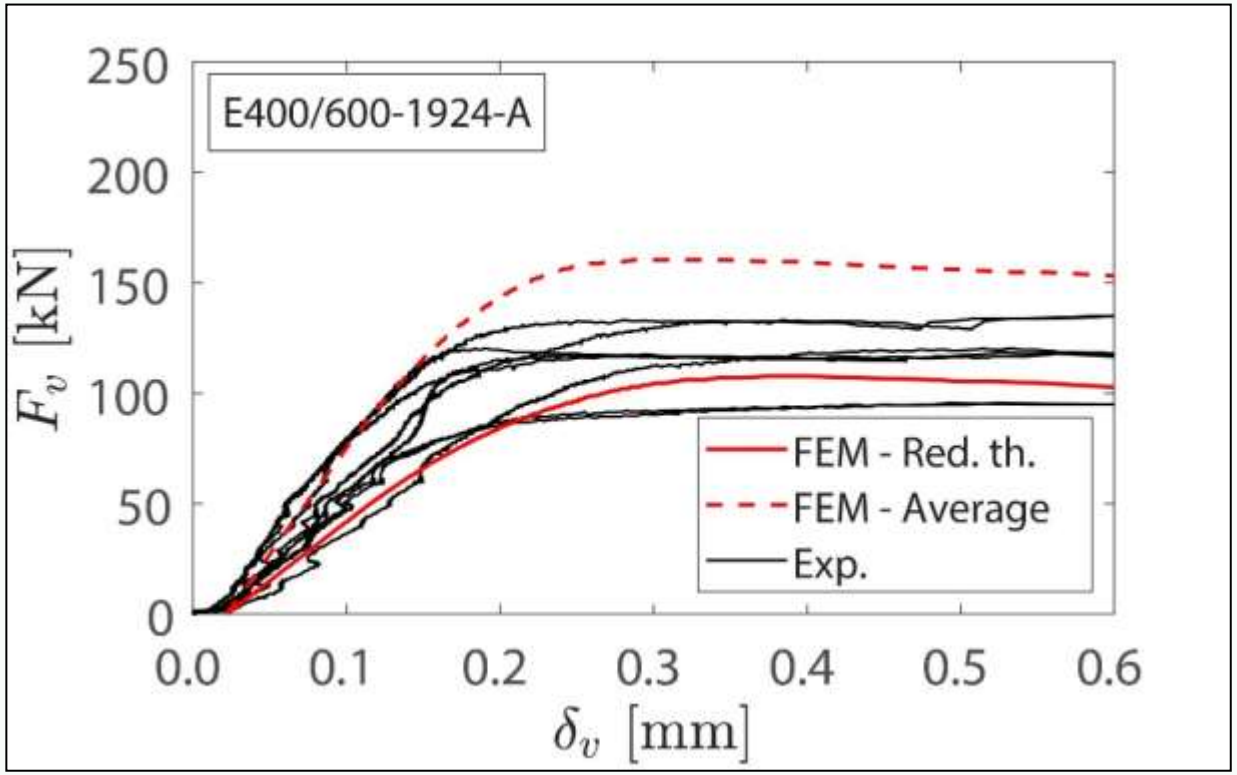
## Reduced wall thickness

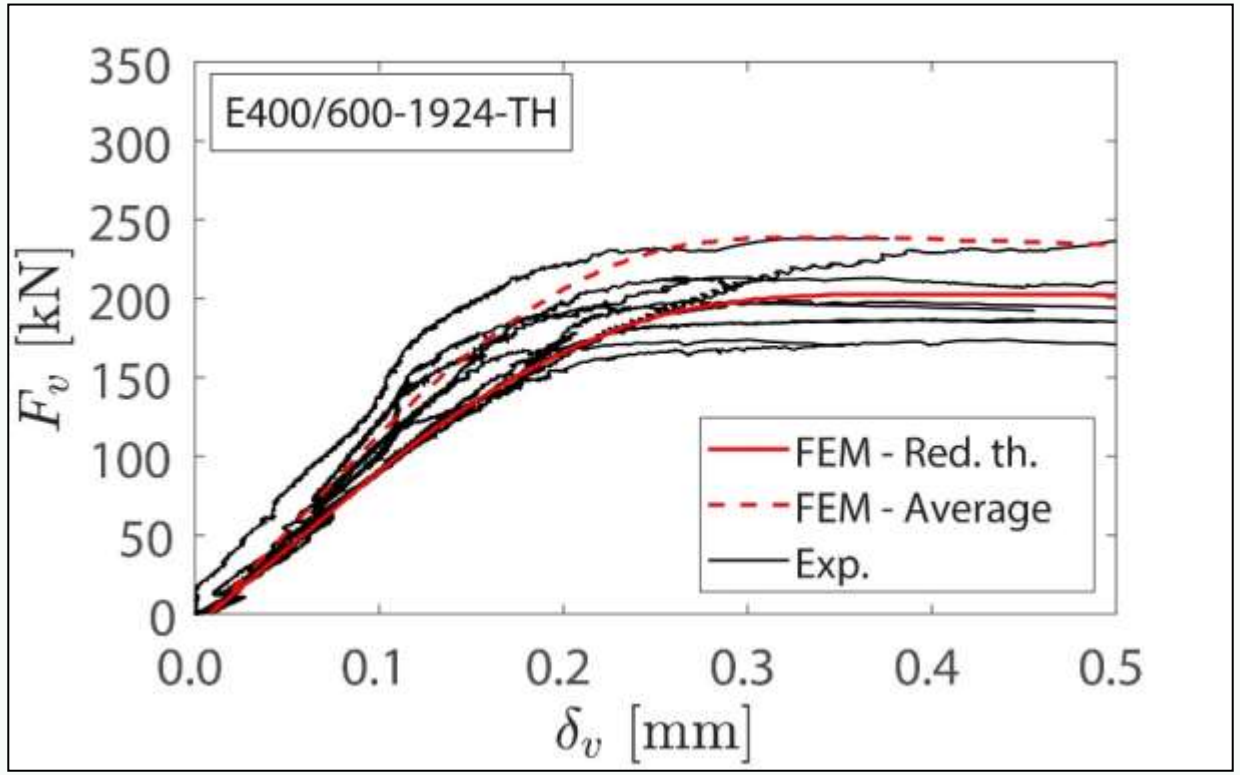



$F_{max;Exp.}$=117kN
$F_{max;FEM}$=108kN (-8%)




$F_{max;Exp.}$=207kN
$F_{max;FEM}$=203kN (-2%)

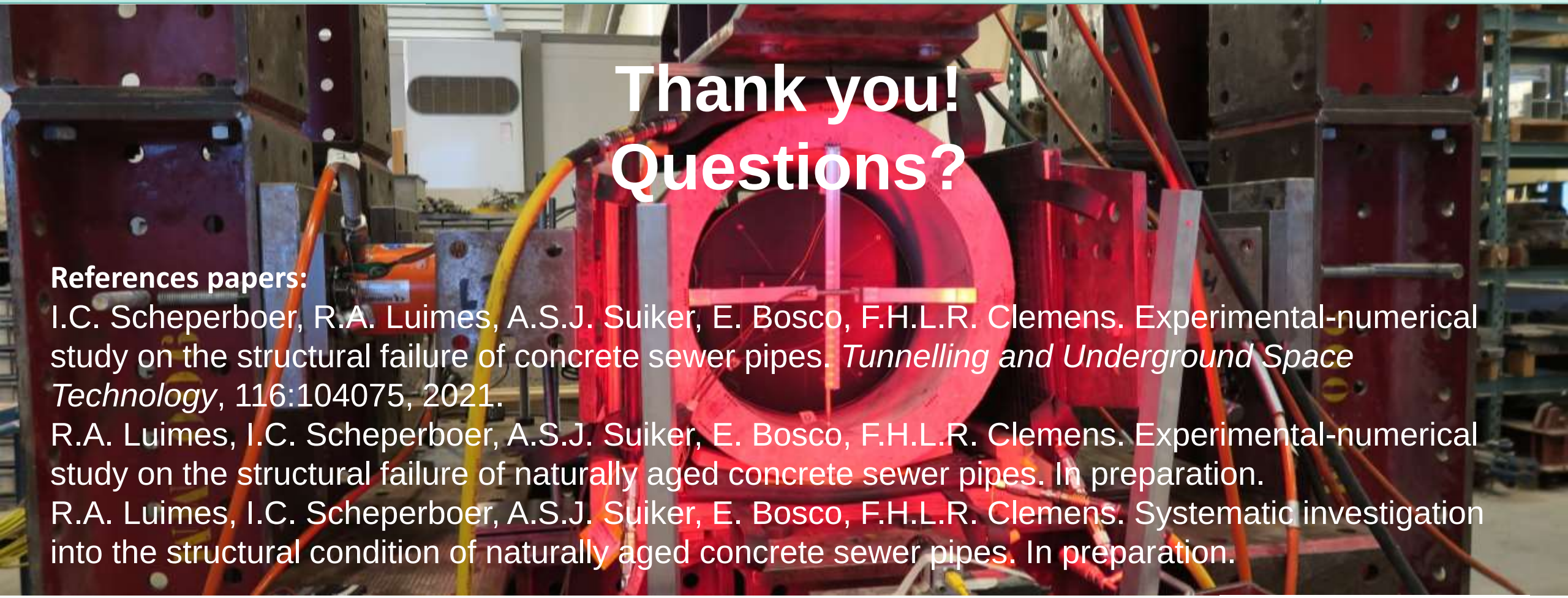


# Conclusions and practical recommendations



- There is no clear relation between visual inspection and remaining load-bearing capacity
- Overall trend naturally aged vs new sewer pipes: Lower compressive and tensile strength and higher mode I fracture toughness.
- At least a part of the area of reduced alkalinity at the inside of the sewer pipes does not contribute to the lead-bearing capacity.
- Regularly monitoring and documenting data on the remaining wall thickness and residual alkalinity across the wall thickness of concrete sewer pipes.
- The practical range of material properties presented for all naturally aged sewer pipes can be consulted by various stakeholders when making structural performance calculations.



# Thank you!
# Questions?

**References papers:**
I.C. Scheperboer, R.A. Luimes, A.S.J. Suiker, E. Bosco, F.H.L.R. Clemens. Experimental-numerical study on the structural failure of concrete sewer pipes. *Tunnelling and Underground Space Technology*, 116:104075, 2021.
R.A. Luimes, I.C. Scheperboer, A.S.J. Suiker, E. Bosco, F.H.L.R. Clemens. Experimental-numerical study on the structural failure of naturally aged concrete sewer pipes. In preparation.
R.A. Luimes, I.C. Scheperboer, A.S.J. Suiker, E. Bosco, F.H.L.R. Clemens. Systematic investigation into the structural condition of naturally aged concrete sewer pipes. In preparation.

PhD-project
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